Table XIX.—Minimum Proportions.

Iodine, between	1	part in	3,100,000	and	3,521,970
Bromine	,,	1 ,,	77,500,000	,,	84,545,000
Chlorine	,,	1 ,,	1264,000,000	,,	1300,000,000

This series of numbers suggests a quantitative relation of the "minimum proportions" to the atomic and molecular weights of the substances.

On comparing these numbers with those of the two previous groups of bodies, we find that the proportion of substance required to upset the voltaic balance was largest with the oxygen salts, intermediate with the haloid ones, and least with the free elementary bodies. It was smaller the greater the degree of chemical energy of the substance; thus it was about 400 times less with chlorine than with iodine. And it was smaller the greater the degree of freedom to exert that energy; thus it was about 5,416,000 times smaller with free chlorine than with potassic chlorate, or 1,570,000 times less than with the combined chlorine of the chlorate; and about 185 times smaller than with potassic chloride, or 88 times less than with the combined chlorine of that salt.

At the lowest potentials, the rate of increase of electromotive force per grain of substance is usually larger the smaller the proportion of substance necessary to disturb the potential. Iodine is an exception to this, but probably only an apparent one, because on substituting magnesium for the zinc, the addition of iodine caused an increase of potential as usual.

The curve of variation of potential was different with the solution of each substance, and was apparently characteristic of the body in each case; and a great number of such representative curves might be obtained by change of strength of solution, in nearly all electrolytes, with a zinc-platinum or other voltaic couple.

IV. "The Electric Organ of the Skate. The Electric Organ of *Raia radiata*." By J. C. Ewart, M.D., Regius Professor of Natural History, University of Edinburgh. Communicated by Professor J. Burdon Sanderson, F.R.S. Received June 6, 1888.

(Abstract.)

The first part of this paper is chiefly devoted to a comparison of the electric organs of *Raia radiata*, *R. batis*, and *R. circularis*. It is shown that the organ in the species *radiata* differs in many respects from the organ in the two other species, and that an exhaustive

study of its structure and development is likely to throw considerable light on the nature of electric organs generally, and also on the structure of the motor plates of muscles. While *R. batis* may reach a length of over 180 cm., *R. radiata* seldom measures more than 45 cm. from tip to tip, and is thus only about half the size of a large *R. circularis*. In *R. radiata* the electric organ is absolutely and relatively extremely small. In *R. batis* the electric organ may be 60 cm. in length and 7 cm. in circumference at the centre, and extend from the skin to the vertebral column, but in an adult *R. radiata* the organ is seldom over 13 cm. in length and 8 mm. in circumference, and the posterior two-thirds is confined to a narrow cleft between the skin and the great lateral muscles of the tail. Further, the organ of *R. radiata* consists of minute shallow cups, which only remotely resemble the large well-formed electric cups of *R. circularis*. In the latter species the various layers of the electric cup are readily comparable to the more important layers of the electric disk of *R. batis*, but in *R. radiata* the electric cup is little more than a muscular fibre, with one end expanded and slightly excavated to support a greatly enlarged motor plate, in which terminate numerous nerve-fibres. The striated layer of *R. batis* and *R. circularis*, which consists of characteristic lamellæ having an extremely complex arrangement, is entirely absent from *R. radiata*, the electric layer is indistinct, and instead of a thick richly nucleated cortex, the cup is merely invested by a slightly thickened sarcolemma. Further, the tissue forming the shallow, thick-walled cup, both in its appearance and consistency, closely resembles an ordinary muscular fibre, while the long stem usually remains distinctly striated to its termination.

In the second part of the paper an account is given of the development of the electric cups of *R. radiata*. It is shown that the rate of development compared with *R. circularis*, but more especially with *R. batis*, is extremely slow. The young *R. radiata* is nearly double the size of the *R. batis* embryo before the muscular fibres reach the "club" stage, and the long nearly uniform clubs, instead of at once developing into rudimentary cups as is the case in *R. batis*, assume the form of large Indian clubs. When the young skate reaches a length of about 35 cm., the long secondary (Indian) clubs begin to expand anteriorly, and this expansion continues until a fairly well moulded cup, mounted on a long delicate stem is produced. But the process of conversion is scarcely completed when the skate has reached a length of 40 cm., *i.e.*, when it has nearly reached its full size, for in the species *radiata* a length of 50 cm. is seldom if ever attained.

The cup-stage having been eventually reached, the stem, which for a time may still increase in length, is often compressed by two or more cups being closely applied together, and part of the rim of the cup may be slightly everted or projected forwards, but even in the

largest specimens of *R. radiata* examined there was never any indication of retrogressive changes.

The small size of the electric organ, together with the shallowness of the minute cups of which it consists, seems at first to indicate that in *R. radiata* we have an electric organ in the act of disappearing. But when the organ of the species *radiata* is carefully compared with the organ of the species *batis* and *circularis*, the evidence seems to point in an opposite direction, and the view that the cups of *R. radiata* are in process of being elaborated into more complex structures, such as already exist in *R. circularis*, is apparently confirmed by the developmental record. Were the electrical organ of *R. radiata* a mere vestige of a larger structure which formerly existed, we should expect to find the motor (electric) plate incomplete, or only occupying a portion of the electric cup and the nerves proceeding to it, either few in number or undergoing degenerative changes. But instead of this we have a relatively large bunch of extremely well-developed nerves proceeding to the electric plate, which is not only complete, but extends some distance over the rim of the cups. Further, there is no indication of the walls of the cup having ever consisted of extremely complex lamellæ, such as we have in *R. circularis*. They consist of a nearly solid mass of muscular tissue, scarcely to be distinguished from the unaltered adjacent muscular fibres. The electric cup of *R. radiata* may in fact, when its structure alone is considered, be said to be a muscular fibre which has been enlarged at one end to support a greatly overgrown motor plate. But the development of the electric cups is even more suggestive than their structure. Had the muscular fibres in *R. radiata* assumed the form of clubs before the young skate escaped from the egg capsule; had the clubs been rapidly transformed into electric cups; and had the cups soon after reaching completion begun to disappear, the evidence in favour of degeneration would have been complete. But, as has been indicated, the conversion of the muscular fibres into an electric organ is late in beginning, and the clubs having appeared, pass slowly through a prolonged series of intermediate stages before they eventually assume the cup form. Further, as has already been mentioned, in the largest specimens of *R. radiata* examined no evidence was found of retrogressive changes, either in the cup proper, or in the numerous nerves passing to its electric plate. Hence it may be inferred that the electric organ of *R. radiata*, notwithstanding its apparent uselessness and its extremely small size, is in a state of progressive development.